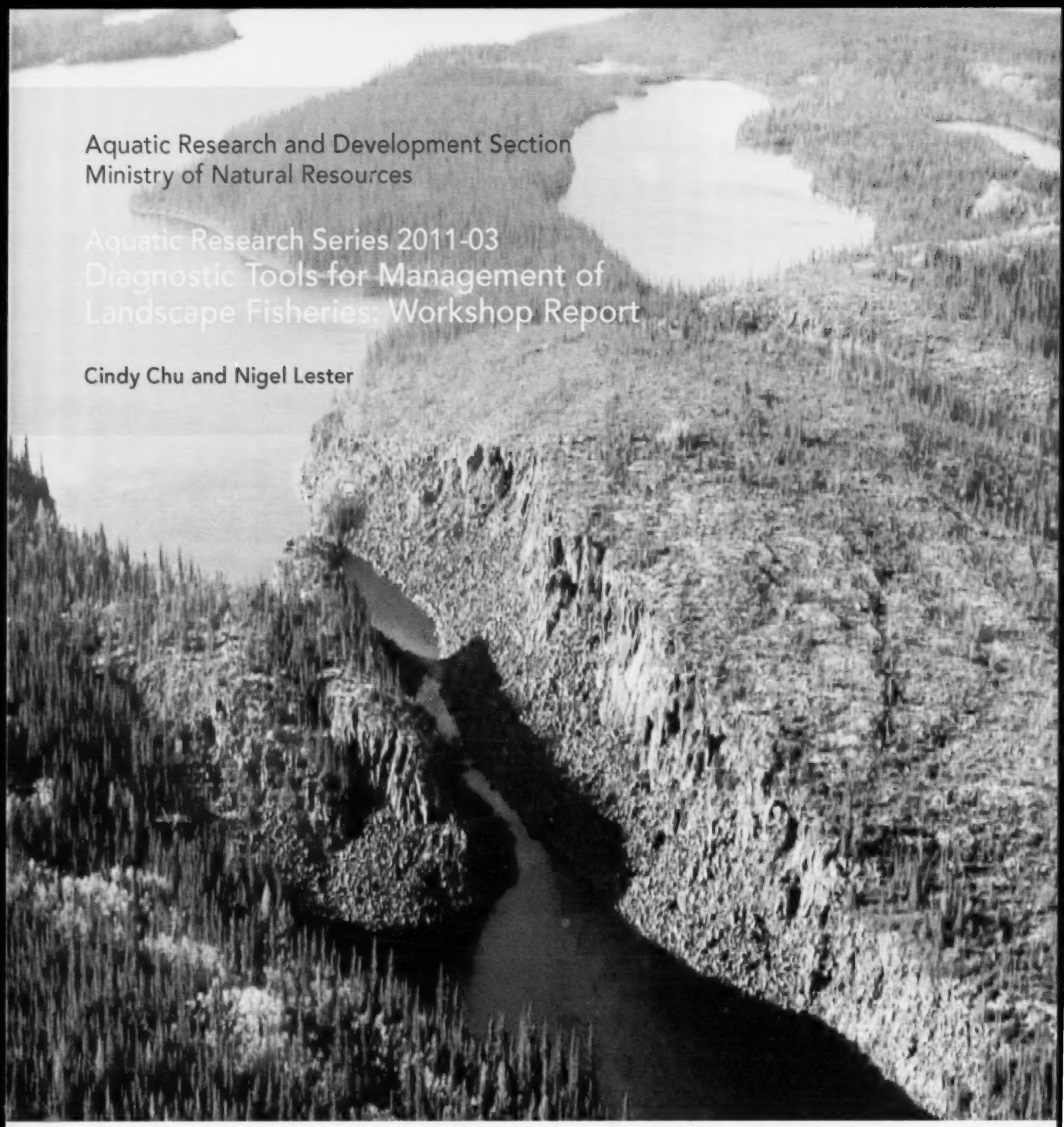

Aquatic Research and Development Section
Ministry of Natural Resources

Aquatic Research Series 2011-03
Diagnostic Tools for Management of Landscape Fisheries: Workshop Report

Cindy Chu and Nigel Lester

Ontario.ca/aquaticresearch

Ontario

November 2011

Diagnostic tools for management of landscape fisheries: workshop report

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Abstract

Ontario's Ecological Framework for Fisheries Management established a 5-year management cycle for Fisheries Management Zones that includes goals and objectives, monitoring and reporting, and evaluation of whether strategic goals are achieved. On March 23-24 2011, the Aquatic Research and Development Section hosted a workshop to report progress and solicit feedback on the development of diagnostic tools for management of landscape fisheries. This report is a summary of the workshop proceedings.

The first half of this workshop focused on sustainable fishing and in particular, the integration of biotic and environmental variables into the models used to determine carrying capacity and natural mortality rate of harvested species in Ontario lakes. This portion of the workshop included a breakout session when participants were asked to comment on abiotic and biotic factors influencing the carrying capacities of walleye, lake trout and brook trout.

The second half of the workshop addressed other goals that apply in fisheries management, related to aquatic biodiversity, ecosystem health, and social and economic benefits. Participants discussed how achievement of these goals may be evaluated. This discussion focussed on identifying indicators, criteria, sources of data, and science needs. The results highlight the extent to which goal achievement can be evaluated given MNR's current commitment to monitoring aquatic ecosystems.

Résumé

Le Cadre stratégique pour la gestion écologique de la pêche sportive de l'Ontario a établi un cycle de gestion de cinq ans relatif aux zones de gestion des pêches. Ce cadre comprend plusieurs éléments : buts et objectifs, suivi et rapports, évaluation de l'atteinte des objectifs stratégiques. Les 23 et 24 mars 2011, la Section de recherche développement en matière de pêche a tenu un atelier pour faire le point et obtenir une rétroaction sur l'élaboration d'outils diagnostiques pour la gestion des pêches à l'échelle du paysage. Cet article présente un compte rendu sommaire de l'atelier.

La première partie de l'atelier portait principalement sur la pêche durable, en particulier sur l'intégration de variables biotiques et environnementales aux modèles utilisés pour déterminer la capacité de charge des lacs de l'Ontario et le taux de mortalité naturelle des espèces qui y sont capturées. Elle incluait une séance en petits groupes, dont les membres s'exprimaient sur les facteurs biotiques et abiotiques influant sur la capacité de charge relative au doré jaune, au touladi et à l'omble de fontaine.

La seconde partie de l'atelier portait sur d'autres objectifs propres à la gestion des pêches touchant les aspects suivants : biodiversité aquatique, santé de l'écosystème, avantages sociaux et économiques. Les participants ont discuté des façons possibles d'évaluer l'atteinte de ces objectifs. Leurs échanges ont porté sur les indicateurs, les critères, les sources de données et les besoins sur le plan scientifique. Les résultats des délibérations indiquent dans quelle mesure on peut évaluer l'atteinte des objectifs eu égard à l'engagement du MRN en matière de surveillance des écosystèmes aquatiques.

Diagnostic Tools for Management of Landscape Fisheries: Workshop Report

(March 23-24, 2011, Peterborough, ON)

Cindy Chu and Nigel Lester

Aquatic Research and Development Section

Ontario Ministry of Natural Resources

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1. Workshop Overview and Agenda

The Ecological Framework for Fisheries Management established a 5-year management cycle for Fisheries Management Zones that includes goals and objectives, monitoring and reporting, and evaluation of whether strategic goals are achieved. On March 23-24 2011, the Aquatic Research and Development Section hosted a workshop to report progress and solicit feedback on the development of diagnostic tools for management of landscape fisheries. This report is a summary of the workshop proceedings.

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Agenda

Wednesday, March 23
9:00 – 9:15 – Welcome and Introductions

9:15 – 10:30 – Presentations

N. Lester	Science for management of landscape recreational fisheries
K. Minns	Measuring the supply of productive habitat for fishes in lakes
N. Lester/B. Shuter	Exploitation reference points for lake trout and walleye

10:45 – 12:15 – Presentations

M. Ridgway	Towards a brook trout model
D. Jackson/K. Alofs	Impacts of smallmouth bass
B. Jackson	Bass stories from NW Ontario
A. Paterson	Potential applications of water quality data from the Broad-scale monitoring program

1:00 – 3:45 – Species exploitation models - Breakout sessions

1. Lake trout and walleye
2. Brook trout

4:00 – 5:00 – Presentation

H. Ball/W. Dunlop	Provincial perspective on management goals for inland lakes

7:30 – 9:00 – Presentations

L. Hunt	Landscape patterns of overfishing
N. Jones	Stream-lake networks: watershed-scale management and ecology
K. McCann	Biodiversity and the adaptive capacity of lake food webs

Thursday, March 24
8:30 – 11:00 – Evaluating achievement of management goals - Breakout sessions

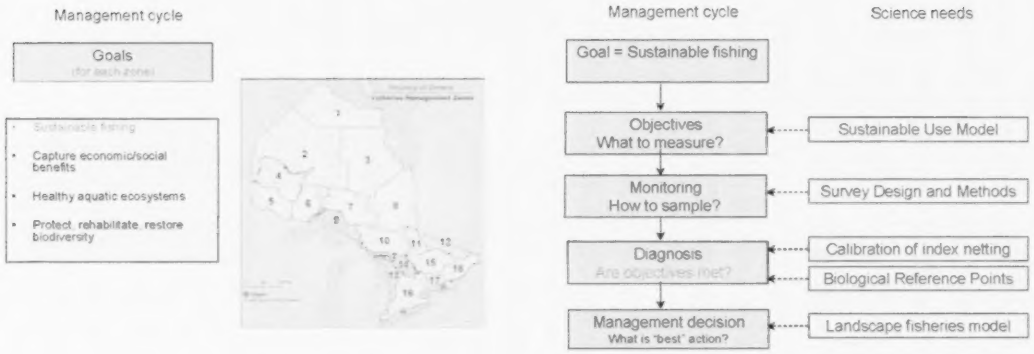
Goal 1: Use Ontario's resources sustainably
Goal 2: Capture social and economic benefits from fish resources
Goal 3: Protect, rehabilitate and restore fish populations and aquatic biodiversity
Goal 4: Protect and rehabilitate aquatic habitat and ecosystems

11:00 – 12:00 – Wrap-up

2. Summary of Presentations

2.1 Science for management of landscape recreational fisheries

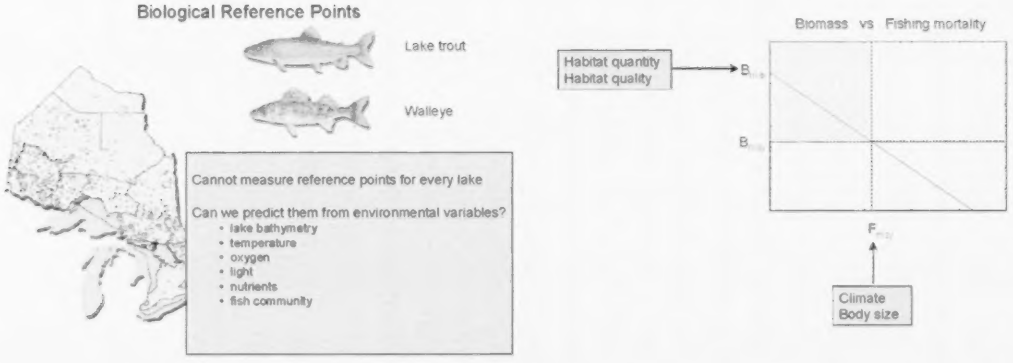
Nigel Lester, Aquatic Research and Development Section



Science needs are driven by management goals. One important goal in Ontario is sustainable fishing. Science needs related to this goal were identified and briefly described. The first day of the workshop focused mainly on building models to evaluate the goal of sustainable fishing (i.e., biological reference points). On the second day, participants were asked to discuss how we could evaluate achievement of other management goals (as listed in the first slide above).

2.2 Exploitation reference points for lake trout and walleye

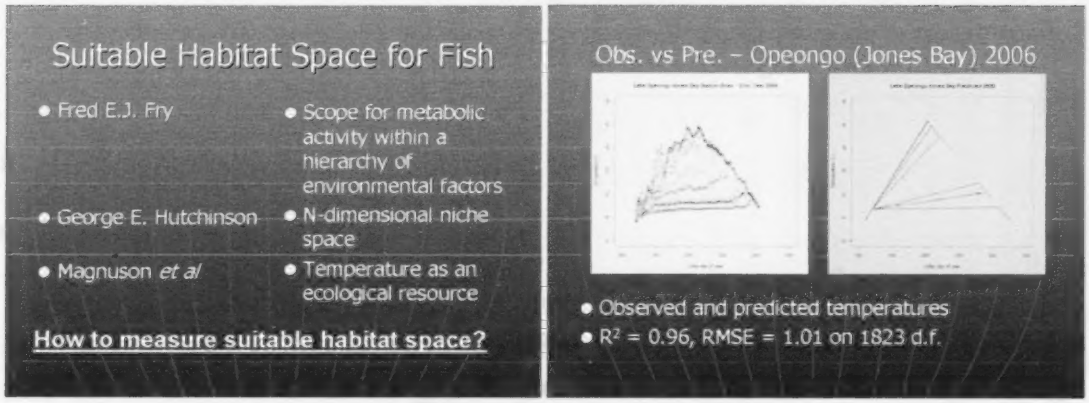
Nigel Lester and Brian Shuter, Aquatic Research and Development Section



Biological reference points for evaluating exploitation can be predicted from environmental variables. In short, (1) the carrying capacity of a given species in a given lake can be predicted from lake habitat and (2) fishing mortality rate that produces maximum sustained yield can be predicted by climate and body size of the fish species. Expansion of the framework shown in the second slide provided a basis for discussions during the first breakout session (see section 3).

2.3 Measuring the supply of productive habitat for fishes in lakes

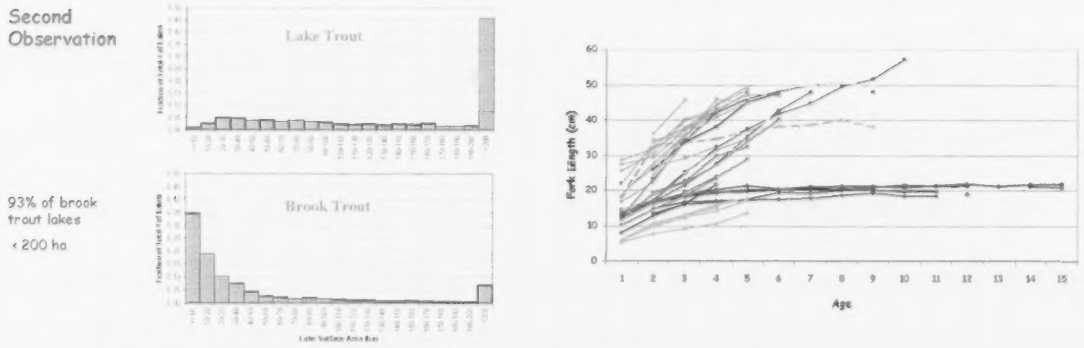
Ken Minns, University of Toronto


Suitable Habitat Space for Fish
• Fred E.J. Fry
• Scope for metabolic activity within a hierarchy of environmental factors
• George E. Hutchinson
• N-dimensional niche space
• Magnuson *et al*
• Temperature as an ecological resource
How to measure suitable habitat space?
Obs. vs Pre. – Opeongo (Jones Bay) 2006
• Observed and predicted temperatures
• R^2 = 0.96, RMSE = 1.01 on 1823 d.f.

The thermal regime of a lake is an important determinant of suitable habitat for fish species. This talk described progress in developing models that predict the seasonal thermal regime based on easily measured variables (e.g. air temperature, lake morphometry). These models will be very useful for predicting a lake's carrying capacity for a given species (which is needed to develop biological reference points) and for predicting effects of climate change.

2.4 Brook trout life history

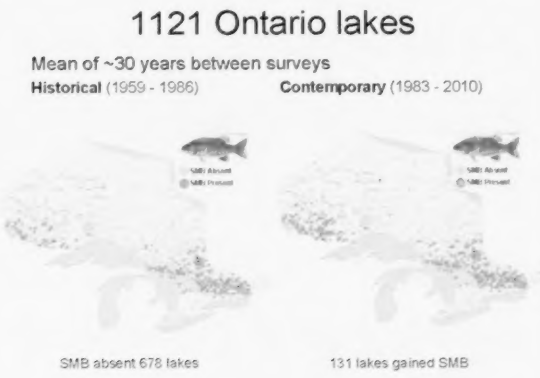
Mark Ridgway, Aquatic Research and Development Section

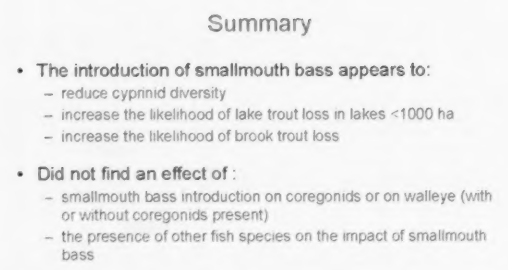


This presentation provided important background for developing biological reference points for management of brook trout. It showed how the biphasic growth model helps to understand the life history variation observed among brook trout populations.

2.5 Insight on the impacts of smallmouth bass introductions

Karen Alofs and Don Jackson, University of Toronto


1121 Ontario lakes
Mean of ~30 years between surveys
Historical (1959 - 1986)
Contemporary (1983 - 2010)
SMB absent 678 lakes
131 lakes gained SMB

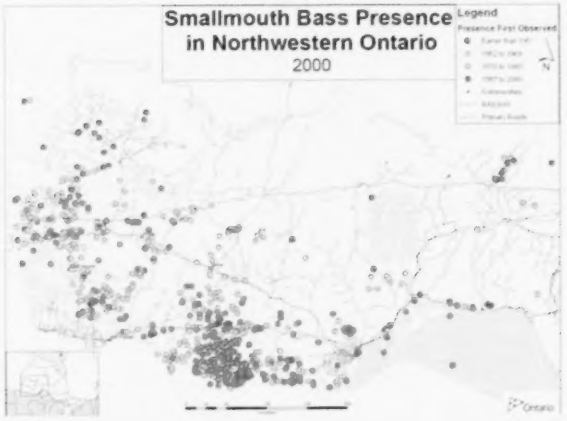

Summary
• The introduction of smallmouth bass appears to:
– reduce cyprinid diversity
– increase the likelihood of lake trout loss in lakes <1000 ha
– increase the likelihood of brook trout loss
• Did not find an effect of :
– smallmouth bass introduction on coregonids or on walleye (with or without coregonids present)
– the presence of other fish species on the impact of smallmouth bass

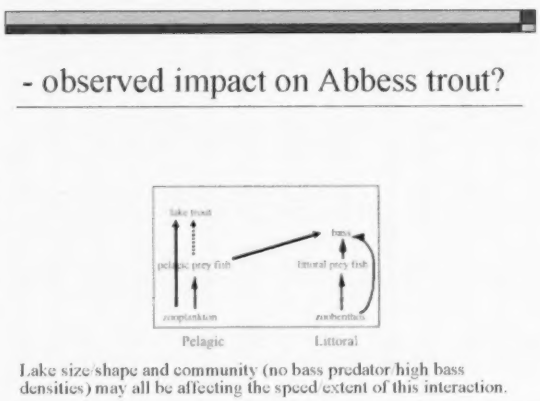
This presentation summarized recent studies that have investigated impacts of smallmouth bass expansion in Ontario and conducted analyses based on historical MNR surveys separated by approximately 30 years. Analyses indicated that smallmouth bass introductions:

- reduced cyprinid diversity,
- increased the likelihood of brook trout loss, and
- increased the likelihood of lake trout loss in lakes < 1000 ha

2.6 Bass stories from northwest Ontario: spread and impact of bass and why it matters to Broad-scale Monitoring

Brian Jackson, Atikokan Area, OMNR



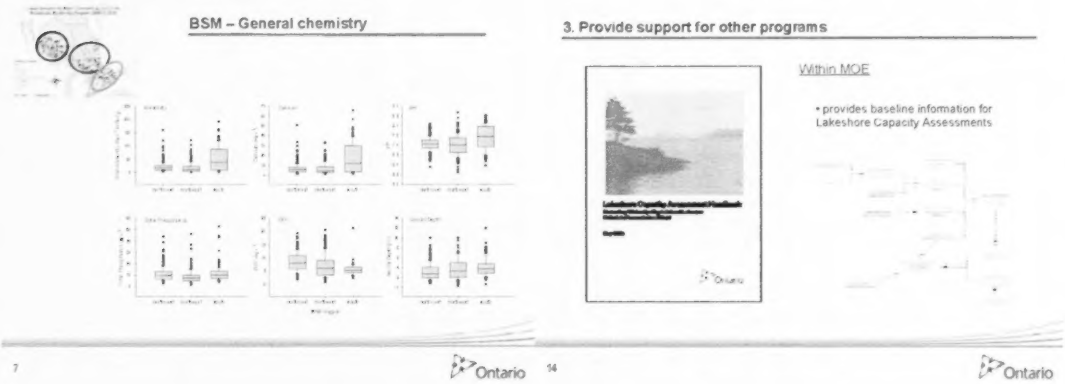


Lake size/shape and community (no bass predator/high bass densities) may all be affecting the speed/extent of this interaction.

This talk described the spread of smallmouth bass that has occurred in NW Ontario since the 1950s and presented results from Atikokan area to demonstrate effects of climate on bass growth (in number and size). A case study (Abbess Lake) demonstrated how increasing bass abundance may be impacting lake trout in small lakes.

2.7 Potential applications of water quality data from the Broad-scale Monitoring Program

Andrew Paterson, Ministry of Environment, Dorset



This presentation described how the BsM water quality data can be used by MOE to describe spatial and temporal trends and to support other programs (e.g., lakeshore capacity assessment). It highlighted the need for MNR and MOE to collaborate in developing data management and analysis tools and planning reports.

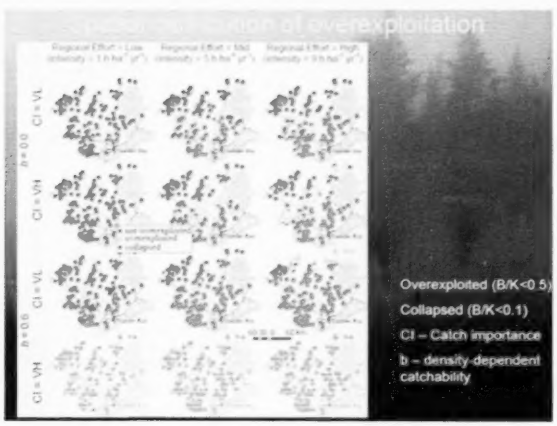
2.8 Provincial perspective on management goals for inland lakes

Helen Ball and Warren Dunlop, Fisheries Policy Section

This presentation provided background information for the second breakout session. See summary in section 4.

2.9 Landscape patterns of overfishing

Len Hunt, Centre for Northern Forests and Ecosystems Research



Conclusions – Critical uncertainties

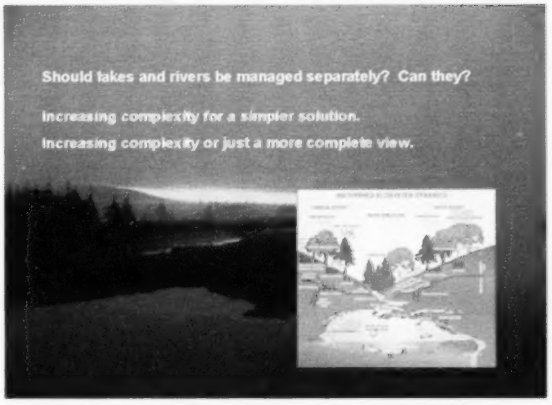
- Knowledge of regional effort, angler behaviours (catch importance) and catchability are all needed
  - Angling effort
    - Simplistic
    - Increased overfishing concerns
  - Catch importance (angler mobility)
    - Complex
    - Context dependent
      - Increased overfishing concerns (collapse)
      - Decreased overfishing concerns (self-regulation)
  - Density-dependent catchability (angler harvest efficiency)
    - Complex (affects both efficiency and mobility)
    - Sharpens relative overfishing effects
    - Reduces attractiveness of productive stocks

This presentation described the development and application of a landscape fishery model for predicting the spatial distribution of fishing effort and patterns of overexploitation. It stressed the need to combine social factors (i.e., that motivate anglers' decisions) and biological factors (i.e., that determine abundance of fish in lakes) when predicting the outcome of a management scenario. This work highlighted the developments in science that are needed to manage fisheries at the landscape scale.

2.10 Stream-lake networks: watershed-scale management and ecology

Nick Jones, Aquatic Research and Development Section

Flowing waters have become important ...
Walkerton – Source water protection
Renewable Energy - hydropower
Far North – land use planning
Parks – aquatic representation
Fish harvest – numerous rivers across Ontario
The invasive and at risk – many spp are riverine
Climate Change – shifting spp range
However, we lack understanding about their ecology and inventory/assessment methods.

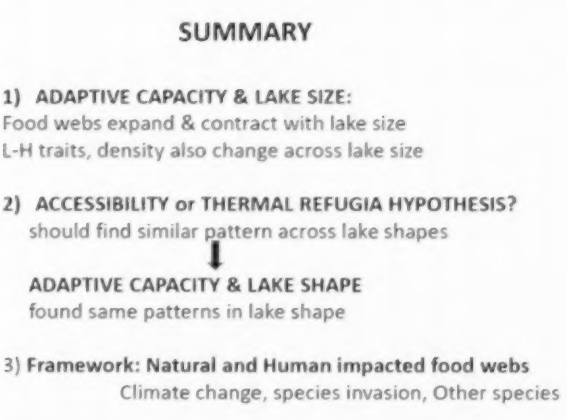

Should lakes and rivers be managed separately? Can they?
Increasing complexity for a simpler solution.
Increasing complexity or just a more complete view.

Ontario has been a leader in developing "lake" science, whereas most of the "river" science has come from relatively lakeless landscapes. This talk stressed the need to study and manage our aquatic ecosystems as stream-lake networks. It described abiotic and biotic interactions between lakes and streams, illustrated how these networks can be described and how aquatic ecosystems can be classified. Progress in developing techniques to describe and monitor aquatic resources at this scale is needed to address the evolving strategic direction of MNR.

2.11 Biodiversity and adaptive capacity of lake food webs

Kevin McCann, University of Guelph

Biodiversity
Biological diversity or biodiversity refers to the variety of life, as expressed through genes, species and ecosystems, that is shaped by ecological and evolutionary processes.
...
Over the past 25 years, countries around the world have recognized that the power of human activity to alter our ecosphere must be brought into better balance with the capacity of the Earth to absorb human impacts.
Ontario Biodiversity Strategy, 2005


SUMMARY
1) ADAPTIVE CAPACITY & LAKE SIZE:
Food webs expand & contract with lake size
L-H traits, density also change across lake size
2) ACCESSIBILITY or THERMAL REFUGIA HYPOTHESIS?
should find similar pattern across lake shapes
ADAPTIVE CAPACITY & LAKE SHAPE
found same patterns in lake shape
3) Framework: Natural and Human impacted food webs
Climate change, species invasion, Other species

This presentation summarized research aimed at understanding the adaptive capacity of natural systems and how human intervention may cause a loss of adaptive capacity. Shield lakes are good natural experiments because they are relatively pristine and have similar levels of productivity. Diversity of food webs and life history in lake trout ecosystems is largely due to constraints on access to food (related to lake size, shape and climate). This understanding of natural variability provides a framework for predicting effects of human impacts.

3. Breakout session 1: Building models to predict biological reference points for walleye, lake trout and brook trout

A key requirement for evaluating sustainable fishing in Ontario's lakes is the development of exploitation reference points for exploited species. As described in the model presented by Lester and Shuter (see Fig. 1), these reference points for a given species will vary among lakes depending on the carrying capacity (B_{max}) and natural mortality (M) of the population. The proposed model claims that:

- carrying capacity depends on habitat quantity (i.e., suitable living space) and habitat quality (i.e. food production and access to food)
- natural mortality rate depends on life history traits

Environmental factors that can affect these variables include:

- Lake bathymetry
- Climate (GDD or Mean air temperature)
- Water temperature
- Oxygen
- Nutrients (TDS or Total Phosphorus)
- Water clarity
- Lake size

The current model is weak in accounting for the influence of biotic factors on exploitation reference points. The only link is that prey size spectrum affects lifetime growth potential which impacts body size and consequently natural mortality (Fig. 1). An important missing factor is the presence of other predators. Their impact on the target species depends, presumably, on the degree of spatial overlap with the target species and consequences resulting from competition for food resources and predation on the target species.

Participants were asked to explore (1) the effects of coexistence, cisco, environmental conditions and other predators on lake trout and walleye carrying capacity and life history characteristics, and (2) the factors influencing brook trout carrying capacity and life history characteristics.

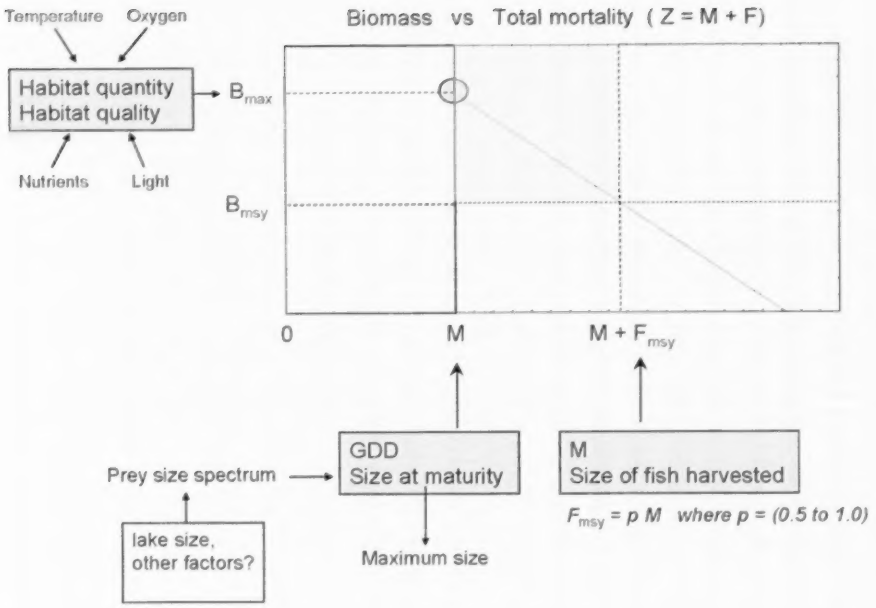


Figure 1. Schematic depicting the influences of environmental and biological factors on the carrying capacity and maximum sustainable yield of target species. Symbols are: M - natural mortality rate, F – fishing mortality rate, GDD – Growing Degree Days, MSY = Maximum sustainable yield, B_{max} – carrying capacity.

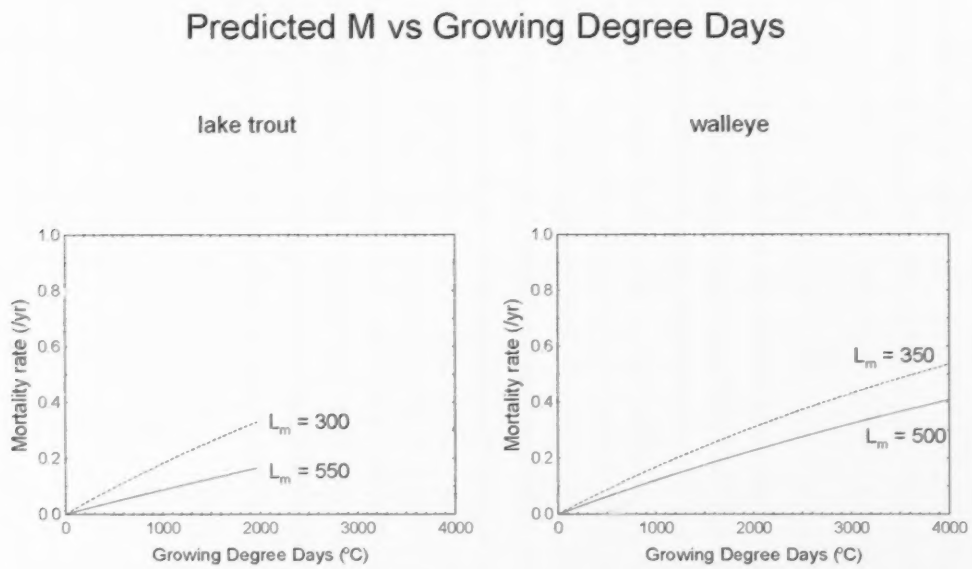


Fig. 2. Influence of climate (growing degree days) and size of maturation (L_m – mm) on natural mortality rate of lake trout and walleye.

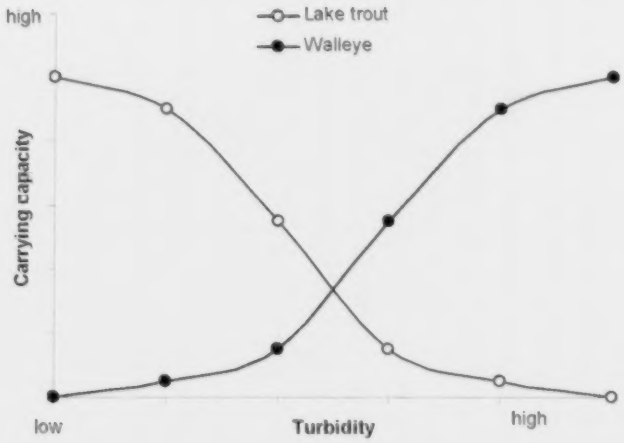
3.1. Lake trout and walleye breakout groups

3.1.1. How does coexistence of lake trout and walleye affect carrying capacity and life history of each species?

The responses to this question addressed the carrying capacity, life history and nature of the competitive interaction between lake trout and walleye.

Carrying capacity:

- B_{max} will be reduced for both due to competition for prey resources
- BsM data shows CPUE reduced for both species when both walleye and lake trout are present
- B_{max} could be inversely related along a gradient (e.g., turbidity) with sigmoidal curves in different directions



Life history characteristics:

- maximum size will shift
- if walleye present, relative abundance of 'small' lake trout is reduced
    - there can be a shift of the entire size distribution of lake trout to the right (larger)
    - or the size distribution may be skewed to the right but no change in maximum sizes observed
    - the latter suggests imposition of predation window on smaller lake trout possibly due to direct predation by walleye on lake trout OR by increased cannibalism by lake trout perhaps driven by depletion of common prey resources by walleye

Competitive interaction:

- There is the expectation that walleye would have a competitive advantage over lake trout because they are able to feed efficiently in more habitats (littoral and pelagic) than lake trout (just pelagic)
- Walleye typically introduced to depress lake trout populations, which can hinder ability of lake trout to recover
- Coexistence is relatively rare in some regions of the province because natural systems do not provide the kind of conditions where both species can thrive
- Coexistence may result in shifts in habitat use or shift in prey resources
- Intensity of competition would vary seasonally

3.1.2. Cisco is an important coldwater resource that supports larger body size in both species, so we expect competition for this resource will affect lifetime growth pattern and carrying capacity of each species. Who wins in terms of carrying capacity?

Who wins depends on – lake size, exploitation, community complexity (size spectrum of prey: cisco, smelt, whitefish)

- Expect that cisco should be more vulnerable to walleye than lake trout because:
  - walleye can feed on them under low light conditions when they are not schooling;
  - young cisco occupy warmer shallower waters that are more accessible to walleye than lake trout
- Competition between walleye and lake trout for cisco is likely to be indirect with walleye feeding at night and lake trout feeding in the day
- Cisco presence potentially expands thermal scope of each species for foraging

Size of cisco depends on predator because walleye are gape size limited (see Vascotto thesis):

- Lakes with walleye only → large cisco
- Lakes with lake trout only → small cisco

If walleye introduced to lake trout lake with cisco:

- Expect cisco size distributions to be strongly impacted
- At >~300mm TL walleye diet moves towards cisco, small difference could lead to larger cisco causing less cisco to be available for lake trout
- Shift in cisco size can cause competition between cisco and juvenile lake trout for resources

If lake trout introduced to a lake with large walleye (due to cisco) at low density:

- Introductions of lake trout will decrease walleye growth, decrease size at maturation, increase mortality
- Prey alternative to cisco can buffer the effects of lake trout

Science need: What happens in lake trout lakes without cisco when walleye are introduced? High density lake trout lakes usually have diverse prey base that could provide alternative prey for walleye.

3.1.3. Are the effects discussed above dependent on lake size or other environmental factors?

Lake size:

- Coexistence more likely in larger lakes (>1000ha) where enough suitable habitat exists for each species (walleye: littoral/pelagic, lake trout: pelagic)
- In small lakes <1000ha lake trout do not make it likely due to walleye predation on juvenile lake trout
- Large lake can mitigate competitive interaction

Other environmental factors:
Thermal-optical habitat (TOHA):
Temperature

- Important factor across range of each species

Water clarity

- In clearer lake trout lakes – walleye are less abundant than in more turbid lakes but walleye are large in size
- Increase water clarity: decrease walleye abundance, increase lake trout abundance

Lake shape:

- Deep 'bucket' lake instead of 'plate' shape lake may not support enough walleye to impact lake trout as less littoral habitat would be available

Streams:

- Presence of spawning streams are likely important to walleye

Science need: Can BsM data be used to determine coexistence along a gradient of secchi depths or other environmental variables?

3.1.4. How does presence of predators (other than walleye) affect lake trout attributes?

Predators other than walleye cohabiting with lake trout are:

Yellow perch (eggs, larva, YOY)	Lake whitefish (eggs and larva)
Northern pike (larva, YOY, juveniles, adults)	Smallmouth bass (larva, YOY, juveniles)
Burbot (juveniles)	Brook trout (larva, YOY, juveniles, adults)
Rainbow smelt (larva)	White suckers (eggs)
Muskellunge (larva, YOY, juveniles, adults)	Cormorants and common loons (juveniles)
Rock bass (eggs and larva)	Cannibalism

Northern pike:

- Coexist with lake trout in lakes of all sizes
- Thermal preferences not thought to overlap and northern pike are littoral/deep littoral typically, but large northern pike can be found at 40 m deep and feed on increasing number of prey types
- Shallow cool lakes of NWT could see predation on lake trout

Burbot:

- Burbot might be causing poor lake trout recruitment in the deep
- When burbot densities decrease, lake trout growth increases

Smallmouth bass:

- reductions in prey and food-web shift

Cannibalism:

- Intensification of lake trout cannibalism likely in situations where prey density much reduced because of intra/inter specific competition

Competitors:

- Northern pike and centrarchids are direct competitors for littoral minnow resources in the shoulder seasons leading to negative effect on lake trout carrying capacity
- Northern pike and centrarchids most competitive feeding in daytime
- Burbot indirect competitors for benthic and littoral resources
- Presence of littoral predators eliminates potential littoral refuge for species that typically spend some time in the pelagic (e.g. young perch)

In general:

- Spatial overlap among predators and competitors affected by timing (diurnal, seasonal) of utilization of prey resources
- Spatial overlap also affected by temperature but need to consider time to equilibrate core temperature – this allows time to forage outside thermal preference

BsM data application:

- Can look at BsM stomach content data to determine interaction b/w/among species
- Can look at BsM data to determine if anglers influence interactions

3.1.5. How does presence of predators (other than lake trout) affect walleye attributes?

Predators other than lake trout cohabiting with walleye are:

Yellow perch (eggs, larva, YOY)	Largemouth bass (larva, YOY, juveniles)
Northern pike (larva, YOY, juveniles, adults)	Smallmouth bass (larva, YOY, juveniles)
Sauger (larva, YOY, juveniles)	Black crappie (eggs, larva, YOY)
Rainbow smelt (larva)	Cormorants and common loons (juveniles)
Muskellunge (larva, YOY, juveniles, adults)	Anglers
Rock bass (eggs and larva)	Cannibalism

Northern pike:

- Northern pike and walleye are negatively associated – relationship is lake size dependent

Largemouth bass:

- In clearer waters walleye inhabit macrophyte beds thus increasing overlap with largemouth bass

Degree of spatial overlap (indicated using +++ = more overlap, + = less overlap):

- Walleye predators: black crappie (++), northern pike NP (++), musky (++), SMB(+), YP(+), LMB(+)

Competitors

- Smallmouth and largemouth bass compete with all ages >0 and bass would out-compete walleye for littoral prey
- Northern pike and yellow perch also compete

In general:

- As level of intra/interspecific competition for food increases, level of cannibalism increases
- Spatial overlap among predators and competitors affected by timing (diurnal, seasonal) of utilization of prey resources

BsM data application:

- Can look at BsM stomach content data to determine interaction b/w/among species
- Can look at BsM data to determine if anglers influence interactions

3.1.6. Comments on the modeling approach

- It might be more effective to try and relate changes in B_{max} to more general community measures like richness and diversity than to species specific indicators such as CPUE values

- MSY should not be presented as a benchmark to shoot for but as a boundary to be avoided by a 'prudent' margin. Considerations that might define prudent quantitatively
  - precautionary principle
  - since the benchmark is to be applied to a set of lakes within a region, the likely frequency distribution of MSY values for the lakes in the region should be used to define a value that is less than some percentile of the distribution

- Reliable resolution of many of these questions can only be arrived at through collection and analysis of BsM-like data collected directly from the systems of concern

3.2. Brook trout breakout group

3.2.1. Explore how this modeling approach (Fig. 1) might work in developing exploitation reference points for brook trout.

- What factors influence the carrying capacity of brook trout?
- What factors influence body size (i.e. size of maturation or maximum size)?
- Does mortality rate vary with body size?
- Does growth rate vary with climate?

Factors affecting brook trout B_{max}:

- suitable habitat supply seasonally
- strong groundwater dependence
- metalimnetic volume
- lake area brook trout in smaller lakes with higher proportion of seepage
- community complexity – cyprinids/suckers, lake trout and coregonids, perch (predator)
- connectivity – lake-stream continuum
- productivity driven by P, related to P
- YOY H requirements, nursery stream habitat

Factors affecting body size:

- life history strategy – sedentary, moving
- prey field
- connectivity lake-stream continuum

Mortality rate decreases with body size

Science need: relationship between brook trout growth rate and climate

3.2.2. How does presence of other predators affect the attributes of brook trout?

1. What predators typically cohabit with brook trout
2. For each cohabiting species, address the following:
    - Use species thermal preferences to describe the degree of spatial overlap with brook trout (focus on summer period first, then consider shoulder seasons)
    - How does lake area/shape affect degree of spatial overlap during summer, recognizing that species are likely to forage in unsuitable thermal habitat for short periods of time if food is limited in their preferred thermal habitat?
    - Are there other factors that may separate the niche of brook trout from co-habiting species?
    - How does presence of the other species affect the availability of large food items for brook trout (and consequently affects maximum size)?
    - Is brook trout likely to be a prey item for the other species? If yes, how does vulnerability of predation vary with life stage (e.g., young of year, juvenile, adult)?

Predators:
Brook trout often out-competed
Thermal preferences - in summer, brook trout are metalimnetic and littoral

Predator (prioritized by impact on brook trout)	Target life stage	Spatial overlap (in summer)	Spatial overlap (other seasons)
Smallmouth bass	YOY, juveniles, adults	+++	+++
Rock bass	eggs, YOY	++	+++
Yellow perch	eggs, YOY, juveniles	+++	+++
Lake trout	YOY, juveniles, adults	+	++
White sucker	Eggs	++	++
Sculpins	Eggs	++	+++
Brown bullhead	Eggs	++	+++
Crayfish	Eggs	++	+++

Lake shape can significantly affect amount of littoral metalimnetic habitat available

Other factors affecting brook trout: groundwater for juveniles and prey preferences

How does presence of other species affect prey for BT and L_z:

- Other species out-compete for large benthic invertebrates; this can affect growth rate and size at maturity
- Cisco-brook trout community is very rare
- Cyprinid-brook trout community is more common

3.2.3 Comments on the modeling approach

- Should consider competitors in the brook trout model
- Brook trout management not as focused on sustainable fishing as lake trout and walleye

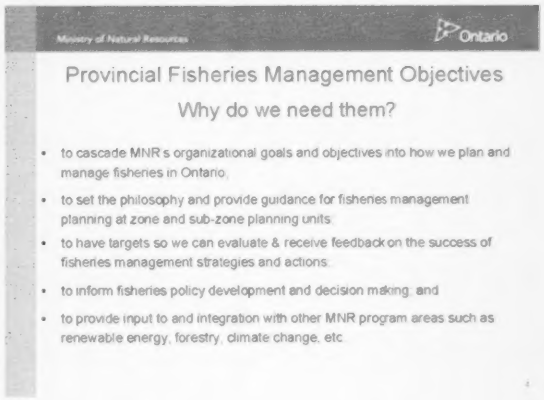
4. Breakout session 2: Evaluating whether management goals are achieved

A presentation by Helen Ball and Warren Dunlop (Provincial perspective on management goals for inland lakes) provided background for the second breakout session. This presentation provided examples of provincial fish management objectives that were derived from strategic directions documents of MNR.

Ministry of Natural Resources — Ontario

MNR Strategic Direction

Strategic Policy	Year	High Level Goal(s)/Objectives				
		Sustainable Use	Protect, Rehabilitate Restore Biodiversity	Healthy Aquatic Ecosystems (protect/rehab)	Capture Economic/ Social Benefits	Stewardship/ Partnerships/ Community Involvement
Our Sustainable Future	2005	X	X	X	X	X
Ontario's Biodiversity Strategy	2005	X	X	X	X	S
Strategic Plan for Ontario Fisheries II	1992	X		X	X	S
Joint Strategic Plan for Management of Great Lakes Fisheries	1997	X		X	X	



Ministry of Natural Resources — Ontario

Provincial Fisheries Management Objectives

Why do we need them?

- to cascade MNR's organizational goals and objectives into how we plan and manage fisheries in Ontario;
- to set the philosophy and provide guidance for fisheries management planning at zone and sub-zone planning units;
- to have targets so we can evaluate & receive feedback on the success of fisheries management strategies and actions;
- to inform fisheries policy development and decision making; and
- to provide input to and integration with other MNR program areas such as renewable energy, forestry, climate change, etc.

The objective of the breakout session was to get participants thinking about how management goals could be evaluated – given MNR's current commitment to monitoring in Fisheries Management Zones.

The strategic goals addressed were:

- Sustainable fishing;
- Capture social and economic benefits from fish resources (food, recreation, culture, employment, income);
- Protect, rehabilitate and restore fish populations and aquatic biodiversity; and
- Protect and rehabilitate aquatic ecosystems;

Working groups were asked to consider objectives identified in existing management plans for fisheries management zones. Each FMZ objective was classified according to the strategic goals listed above. Working groups then discussed how achievement of the objective could be assessed. Specifically, they were asked to identify:

- indicators (what to measure),
- criteria (references points),
- data sources, and
- science needs.

Two primary sources of data were acknowledged as MNR's current commitment to monitoring of the inland (i.e. non Great Lake) FMZs:

- Broad-scale lakes monitoring (BsM) which obtains fish, habitat, and exploitation data for a stratified random sample of lakes within each zone every 5 years; and
- Recreational Fishing Mail survey which surveys a stratified random sample of licensed anglers every 5 years; anglers are asked to report their fishing effort, catch and harvest by waterbody during their previous calendar year.

4.1 Use Ontario's resources sustainably (i.e., sustainable fishing)

This strategic goal implies Ontario will take a precautionary approach in harvesting fish. Provincial management objectives include:

- Limiting the impact of fishing and maintaining the abundance of harvested fish populations above regional benchmarks of sustainablility;
- Minimizing the impact of fisheries and management activities that may affect the diversity, size structure and function of fish populations and communities

Examples of FMZ objectives aligned with this goal are:

- Maintain current abundance levels of walleye, lake trout, northern pike and brook trout (FMZ 6)
- Increase lake trout abundance so that within 20 years 50% of self-sustaining populations have abundance levels that exceed criteria (FMZ 10)
- Increase the proportion of mature female lake trout to 25% (FMZ 10)
- Increase walleye abundance and improve population structure (FMZ 17)
- Provide walleye angling and harvest opportunities based primarily on naturally reproducing walleye populations, but provide other angling opportunities with more liberal regulations to deflect angling pressure away from naturally reproducing populations (FMZ 17)
- Provide increased angling opportunities and harvest of bass, within the context of sustainability (FMZ 17)
- Maintain/enhance the quality of the sunfish fishery, within the context of sustainability (FMZ 17)

Examples of indicators:

- Abundance by species
- Community composition
- Size structure
- Angling effort
- Harvest

Criteria:

- In some cases, criteria are not needed because objectives are simply to maintain, decrease or increase the value of an indicator
- In other cases, reference points are needed that identify what values would be used to assess sustainability

Data sources:

- Many data needs are provided by the combination of BsM surveys and the Recreational fishing mail survey
- BsM provides data on fish populations, community structure and fishing effort for a stratified random sample of lakes
- The mail survey provides estimates of fishing effort and harvest for each FMZ
- Very specific objectives would require additional surveys on some lakes because stratified random-sampling of lakes will not sample the right subset of lakes.

Science needs:

- Sustainability reference points for fish abundance and fishing effort
- Management decision support tool to predict effect of management actions (changing regulations, stocking of some lakes) on the zone-wide spatial distribution of fishing effort and depletion of fish stocks
- Better understanding of the size selectivity and catchability of the BsM netting methods; specifically, how well do these methods work for monitoring Centrarchid populations?

4.2 Capture social and economic benefits from fish resources (food, recreation, culture, employment, income)

This strategic goal implies that, where consistent with sustainability and biodiversity objectives, recreational fishing opportunities and non-consumptive use of fish resources will be increased or improved to enhance contributions of recreational fishing to local, regional and provincial economies. MNR will strive to have an educated public that is aware of the benefits of having healthy fish populations and of the healthful benefits of recreational fishing.

Examples of FMZ objectives aligned with this goal are:

- Increase winter angling opportunities for lake trout (FMZ 6)
- Provide opportunities for consumption of northern pike (FMZ 6)
- Provide year round opportunities for brook trout fishing and relieve angling pressure on native brook trout populations (FMZ 6)
- Enhance the quality of lake trout angling, including the number and size of angled fish (FMZ 10)
- Provide walleye angling and harvest opportunities based primarily on naturally reproducing walleye populations (FMZ 17)
- Provide put-grow-take walleye angling opportunities where more liberal regulations will deflect angling pressure away from naturally reproducing populations (FMZ 17)
- Provide competitive fishing opportunities consistent with the sustainability of the bass fishery (FMZ 17)
- Promote bass fishing and increase bass fishing opportunities within the context of sustainable fishing (FMZ 17)
- Increase and diversify angling opportunities and associated recreational and tourism benefits (FMZ 17)
- Promote muskie fishing and increase muskie angling opportunities (FMZ 17)
- Promote existing high quality fisheries to optimize social and economic opportunities (FMZ 17)

Examples of Indicators:

- Angling effort by species
- Angling catch and harvest by species
- Angling quality
- Spatial distribution of fishing effort (to demonstrate re-distribution of fishing effort)

Criteria:

- In most cases, criteria are not needed because objectives are simply to maintain, decrease or increase the value of an indicator

Data sources:

- The recreational fishing survey provides valuable data for observing zone-scale trends in the character of fisheries (i.e. species targeting, live-release of fish) and economic value
- BsM data are not useful for evaluating whether these objectives are met, but the BsM program provides valuable inventory of fish resources for identifying social and economic opportunities related to fishing
- Some objectives (i.e. spatial re-distribution of fishing effort) would require additional data collection to measure fishing effort on the appropriate set of lakes

Science needs:

- Social science that allows better understanding of factors that determine anglers' decisions and how to influence anglers (i.e. market new opportunities)

4.3 Protect, rehabilitate and restore fish populations and aquatic biodiversity

Provincial fish management objectives aligned with this strategic goal are:

- Increase the abundance and reproductive potential of harvested fish populations through rehabilitation and restoration to achieve regional benchmarks of sustainability
- Protect and recover fish species at risk and other native fish species
- Minimize the introduction and spread of invasive fish and other aquatic species
- Minimize the introduction, intensity and spread of fish disease

Examples of FMZ objectives are:

- Prevent the introduction and spread of invasive species (FMZ 6)
- Prevent the unauthorized transfer or stocking of sport fish (FMZ 6)
- Minimize the introduction and spread of aquatic invasive species, including both exotic and native species (e.g. rock bass, largemouth and smallmouth bass) (FMZ 10)
- Increase the number of self-sustaining lake trout lakes by 20 lakes within 20 years (i.e., recovery from acidification stress) (FMZ 10)
- Contribute to protection or recovery of aquatic species at risk (FMZ 17)
- Reduce the risk of introduction and spread of invasive species and pathogens (FMZ 17)
- Manage northern pike as an invasive species in waterbodies where they have become established (i.e. increase the harvest of northern pike) (FMZ 17)

Indicators:

- Water quality (i.e. habitat for self-sustaining lake trout populations)
- Lake trout abundance
- Invasive species presence
- Pathogen presence

Criteria:

- Water quality reference values for lake trout habitat (suitable pH, alkalinity, dissolved oxygen concentration, TDS)
- Reference values for lake trout abundance (to assess self-sustaining)
- Reference points are not needed for objectives related to invasive species and pathogens because objective is generally to minimize number of infected lakes

Sources of Data:

- Spread of invasive species and pathogens:
    - BsM offers a statistically valid means of measuring spread of invasive fish and zooplankton (i.e., stratified random sample of lakes, sampling protocols for fish and zooplankton); sampling protocols do not exist for other taxa (e.g. mussels, crayfish, other benthic invertebrates) which are reported as incidental observations
    - Angler/public reporting is an important source of information (although not statistically-based)
    - No system exists for tracking pathogens, but BsM design collects fish data that could be used for this purpose
- Tracking rehabilitation of populations (e.g. lake trout in FMZ 10)
    - BsM collects the right type of data, but probably not from the right set of lakes (because the lake sample is stratified random); need to target data collection on the candidate lakes to measure rehabilitation success

Science Needs:

- Establish reference values for lake trout habitat (done) and abundance (in progress)
- Need better education of threats due to invasive species and understanding of causes
- How would public respond to live bait ban? Answer affects management actions available for dealing with invasive species and pathogens.

4.4 Protect and rehabilitate aquatic habitat and ecosystems

Provincial fish management objectives aligned with this strategic goal are:

- Protect and restore the physical and chemical properties of ecosystems that provide fish habitat and support healthy fish populations and viable fisheries
- Protect representative aquatic ecosystems and associated natural and cultural features

Examples of FMZ objectives are:

- Maintain water quantity and quality, sediment quality and water levels within natural ranges suitable for lake trout (FMZ 10)
- Protect, maintain and enhance critical habitat for naturally reproducing walleye populations and associated aquatic communities (FMZ 17)
- Protect and rehabilitate headwater ecosystems to avoid loss of brook trout populations (FMZ 10 hypothetical)

General comments:

- Focus of this goal is on "habitat", but inclusion of the term "ecosystems" creates overlap with goal 3 which acknowledges aquatic biodiversity
- Protection can be viewed at the zone level
    - Could use BsM data to provide zone-wide description of aquatic habitat (e.g., thermal regime, productivity, dissolved oxygen, pH, etc.)
- Rehabilitation is site-specific
    - Case studies needed to test rehabilitation success
    - Could use zonal norms to identify "issue" lakes
- BsM does really address physical habitat in detail, but could use GIS layers to provide more detailed description of habitat and predict stresses related to habitat.

Examples of Indicators:

- Habitat quantity (e.g., walleye spawning substrate, groundwater inputs)
- Water quantity (e.g., water budgets incorporating diversions, inputs, etc.)
- Water quality (e.g., pH, alkalinity, oxygen, TDS, etc.)
- Sediment quality (e.g., contaminants in sediment)
- Water levels

Criteria:

- What are "natural ranges" of habitat variables (e.g. water levels)
- What are safe levels of sediment quality
- How much habitat is enough?

Sources of Data:

- BsM data could be used to monitor changes in water quality at the zone scale
- Geomatics - GIS analysis of zone maps could be used to provide a more detailed description of habitat (assuming map layers are up to date); layers would include watersheds, land use, roads, wetlands, rivers, barriers, etc.; changes in maps through time would describe changes in habitat
- Water levels cannot be obtained from GIS layers (need HYDAT gauge stations)
- Case studies needed to evaluate rehabilitation experiments

Science Needs:

- Habitat models that relate "habitat quantity and quality" relate to "productive capacity"?
- Safe levels (from MOE data)

5. Conclusions

This workshop focused on the need to develop diagnostic frameworks for evaluating whether fisheries management goals for Ontario are being achieved. The first half of the workshop focused on the goal of sustainable fishing. For this goal, the development of a diagnostic framework is progressing well. This framework identifies indicators (i.e., what to measure on lakes) and criteria (i.e., reference values for judging sustainability). It also identifies that (1) the required data are being collected through the Broad-scale Lakes monitoring program; (2) the design of lake selection (i.e., stratified random sampling) is appropriate for this purpose; and (3) the calibration of index netting is needed so that fish biomass can be estimated. The calibration exercise is being led by Science Information Branch and development of reference points is being led by Aquatic Research and Development Section with assistance for academic partners. Given continued progress in the calibration and research activities, we can expect that diagnostic tools for evaluating sustainable fishing of walleye, lake trout and brook trout will be available for the end of the first cycle of the Broad-scale Lakes monitoring program (i.e., 2013).

Progress in developing frameworks for evaluating achievement of other goals is less advanced. These goals relate to socioeconomic benefits and the maintenance of aquatic biodiversity and ecosystem health. Questions raised at the breakout session made it clear that the goals need to be more clearly defined. Regardless, it was obvious that MNR's current commitment to monitoring will not provide sufficient data to support some goals. This exercise assumed that the only sources of data were the Broad-scale lakes monitoring program and the Recreational Fishing mail survey. There is a need to revisit this exercise, after more clearly defining provincial goals, and identify additional data collection commitments that are needed if we intend to report on achievement of goals. It is also becoming obvious that the fisheries business cannot be viewed in isolation from other business of MNR and that fisheries management goals must be nested within broader goals relating to aquatic biodiversity and ecosystem health. The value of current monitoring programs and the need for additional monitoring commitments should be assessed with broader goals in mind. In addition, the fish population models that provide reference points for evaluating sustainable fishing must be broadened into ecosystem models to provide reference points for judging ecosystem health. These observations identify priorities for the development of science in support of management.

Appendix 1. Workshop participants

Participant	Affiliation
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